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ECONOMIC ADAPTATION OF OILSEED CROPS ACROSS SASKATCHEWAN

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I Summary

Harvest has been completed at all 5 sites over three years for the oilseed study, and the following re-cropping study. Challenges from the weather occurred at all sites during 2004. In 2005, hail occurred at Scott, excess moisture reduced plant densities at Melfort and high winds caused shattering reducing canola yield at Redvers. In 2006, hail occurred at Scott and drought affected the results at Redvers. Statistical analysis of the data for both experiments has been carried out. The loss of 2 years of data from Scott forced the removal of this site from the overall analysis. The grain yield of all crops increased as the nitrogen rate increased. On average Canola has the largest nitrogen response while Sunflowers had the lowest response to nitrogen when averaged over all locations. Indian Head and Melfort were the most responsive sites. Swift Current was less responsive than Indian Head or Melfort and yield did not increase at nitrogen rates above 110 kg ha^{-1}. Redvers had the lowest response in this study. Oil content was not affected by any of the treatments. Some "by the seat of your pants" economics are presented in appendix 1 and will need to be refined for publication in a science journal

The re-cropping part of the research project was successfully carried out at all locations except Scott. Grain yield was affected by two interactions, location x previous crop and location x nitrogen rate on the previous crop. There was a linear increase in grain yield at all locations as the N rate increased. In addition, there was a linear increase in grain yield on all previous crops as the N rate increase but the rate of increased among the previous crops was not identical. There was a curvilinear increase in barley protein at Swift Current as the N rate increased while there was a slower linear increase at the other sites as the N rate increased. Test weight, kernel weight and plump seed all decreased as the N rate increased at Swift Current, however, N rate had no effect on these variable at the other three locations.

II Introduction

Canola quality *Brassica juncea* L. (*juncea* canola), and hybrid, oilseed sunflowers (*Helianthus annus* L.) have potential for greatly increased production in western Canada. *Juncea* canola is a recently developed crop with seed quality similar to cultivars of *Brassica napus* L. and *Brassica rapa* L. with canola quality (Woods et al., 1991. and hybrid oilseed sunflowers have largely replaced open-pollinated oilseed sunflowers. (Beckie and Brandt, 1996). The economics of production, which includes the nitrogen (N) response of flax (*Linum ustitatissimum* L.) and *Brassica napus* (*napus* canola) in western Canada have been relatively well researched (Nuttall and Mahli, 1991; Mahli et al., 2007); However, much less is known about the N response of *juncea* canola and hybrid, oilseed sunflowers. If producers are to grow these two oilseed crops they need information on their adaptation and response to N. Currently there is very limited

information comparing the economics of *juncea* canola, and hybrid oilseed sunflowers to established oilseed crops, canola and flax, in the soil-climatic zones of Saskatchewan using current production practices.

Barley producers are often struggling to produce malting quality barley. One problem that growers face is having barley with protein concentrations above the acceptable limit. The oilseed experiment provides an opportunity to examine the effects of previous crops and the nitrogen rate applied to that previous crop on barley yield and quality.

Objectives
To compare the adaptation, N response curves and economic returns *juncea* canola and hybrid, oilseed sunflowers to flax and *napus* canola with in various soil-climatic zones of Saskatchewan.
To compare the effects of the oilseed crops, canola, flax, *Brassica juncea* quality canola and sunflower, on a cereal crop grown in the following year across soil-climatic zones.

III Methods

a. Experiment 1

The response of sunflower and canola quality brassica juncea to nitrogen compared to the nitrogen response of canola and flax

Objective: To determine the nitrogen response of sunflowers across Saskatchewan and how that response differs from alternative oilseed crops currently grown

Test numbers: to keep organized please include the following experimental number assigned to each location on protocol so that we can handle the data as it comes in.

Location	Test Number
Indian Head	04-471
Swift Current	04-472
Melfort	04-473
Scott	04-474
Redvers	04-476

Experimental Design: Split plot design
Plot Size: 35 feet x 8 ft (flexible)
Reps: 3
Treatments:
Main Plot) Crop

1) Sunflower
2) *juncea* Canola
3) Hybrid *napus* canola

4) Flax

Sub-Plot) Nitrogen

1) 10 kg/ha
2) 30
3) 50
4) 70
5) 90
6) 110
7) 150
8) 200

plots 32 x 3= 96

Fertility

P, K and S suggest that a blend be applied we side band a blend of 14-20-10-10 at 100Kg/ha^{-1} to get the N for treatment 1.

Crop	Cultivar	Seeding rate	Herbicide
Sunflower	63M02	7.5/m^2	Edge or trifluralin, assert or select as required
Canola quality *Brassica juncea*	Dahinda	200 seeds/m^2	trifluralin, select as required
Hybrid canola	Invigor 5020	200 seeds/m^2	Liberty and select
Flax	CDC Bethune	300 to 400 plants/m^2 use **62 kg/ha**	Flax Max

Pre-seed burndown with glyphosate for all crops

Locations: Indian Head, Redvers, Swift Current, Melfort and Scott

Data Collection:

a. Soil test: 0-6 inches, 6-24 inches, 24-48 for N bulked across reps, hot KCL for N, 0-6 inches for P, K, and S bulked across the test
b. Soil moisture at seeding 0-12, 6-24, 24-36, and 36-48 by individual plot
c. Soil moisture at harvest 0-12, 6-24, 24-36, and 36-48 by individual plot
d. Soil moisture Oct 15, 0-12, 6-24, 24-36, and 36-48 by individual plot
e. Days to emergence - rows become visible
f. plant density, (minimum of 2-one metre of row per plot)
g. % ground cover 30 days after emergence (Indian Head only with digital camera)
h. Days to ground cover - when ground is covered and rows disappear
i. Days to first 5% of plants flowering
j. Days to last 5% of plants flowering

k. Plant height, (2 per plot)
l. days to maturity,
m. Lodging, (1-9, 1= upright and 9=flat)
n. Grain yield,
o. Gain moisture of sample when weighted
p. Test weight, grams/0.5L
q. 1000 Kernel weight,
r. Retain sub-sample of 150g (for processing)
s. Protein content
t. Oil content

B. Experiment 2

The re-cropping of malting Barley on four oilseed crops and several nitrogen fertilizer rates

Objective: To compare the effects of the oilseed crops, canola, flax, brassica juncea quality canola and sunflower, on a cereal crop (barley) grown in the following year across soil-climatic zones

Experimental Design: Split plot design
Plot Size: 35 feet x 8 ft (flexible)
Reps: 3
Treatments:
Solid seed barley over old treatments
Main Plot) Crop

1) Sunflower
2) *juncea* Canola
3) Hybrid *napus* canola
4) Flax

Sub-Plot) Nitrogen

1) 10 kg/ha
2) 30
3) 50
4) 70
5) 90
6) 110
7) 150
8) 200

plots 32 x 3= 96
Fertility
35 kg/ha of actual N in total be applied at seeding of barley, AC Metcalfe
P,K and S suggest that a blend be applied we side band a blend of 10-20-10-10 at 100 Kg/ha^{-1}

Locations: Indian Head, Redvers, Swift Current, Melfort and Scott

Data Collection:

a. Soil test: for N,P,K and S, 0-6 inches, bulked across reps,
b. plant density, (minimum of 2-one metre of row per plot)
c. Tiller density (# of heads per unit area at maturity, 2- one metre of row per plot)
d. Plant height, (2 per plot)
e. Days to heading
f. days to maturity,
g. Lodging, (1-9, 1= upright and 9=flat)
h. Grain yield,
i. 1st sample: **Retain a 1 kg sub-sample** no chaff or straw - send to IH for processing
j. 2nd sample: **Grn Protein**: can be taken at IH from the 1 kg sample for processing and sent to appropriate lab for analysis

The following measurements done at IH form the 1 kg sample

k. Test weight (use 0.5L cup)
l. 1000 Kernel weight,
m. Plumps, on top of 6/64 x 3/4 slotted sieve
n. Thins, portion going through a 5/64 x 3/4 slotted sieve
o. Grn Protein (as mentioned above)

C. Statistical analysis

Both experiments were analyzed with the Proc Mixed procedure in SAS (Littell et al., 1996). Crop, nitrogen rate and location were considered fixed effects while years and replicates were considered random effects. Locations were considered to be fixed since I wanted to talk about how the adaptation of the crops varied among the locations which I could not easily do if I had set location as random and the locations were not randomly selected but were selected to cover a large portion of the agro-ecology of Saskatchewan. Unfortunately, we lost two of the three years of data at Scott which resulted in the lost of this location in the analysis.

D. Economics

The adjusted gross return was calculated in the following manner:

= (Grain yield * grain price) – (amount of applied N *cost per unit of N)

In the calculations two grain prices, \$200 and \$400 tonne^{-1} and four N costs: 0.85, 1.00,1.15 and 1.30 \$ kg were used.

IV Results

a. Experiment 1

The response of sunflower and canola quality brassica juncea to nitrogen compared to the

nitrogen response of canola and flax

The anova is presented in Table 1.1 All the two way interactions, species x nitrogen (N), location x species, and location x N all affected grain yield. There was a curvilinear increase in grain yield of all four crops as the rate of applied N increased when averaged over locations and years (Figure 1.1). On average napus canola had the largest nitrogen response, grain yield increased as the N rate increased to 200 kg ha^{-1}. A similar response was reported by Mahli et al. (2007). Flax grain yield did not respond to N rates above 90 kg ha^{-1}, while the grain yield of *juncea* canola and sunflower increased as N increased to 70 kg ha^{-1}. Sunflowers had the lowest response to nitrogen when averaged over all locations. Indian Head and Melfort were the most responsive sites (Figure 1.2). Swift Current was less responsive than Indian Head or Melfort and yield did not increase at nitrogen rates above 110 kg ha^{-1}. Redvers had the lowest response in this study. *Napus* canola and flax had similar grain yields at each location and never had a yield lower than sunflower or *juncea* canola at any (Table 1.2). The yield of *napus* canola and flax was greater than sunflower or *juncea* canola at Indian Head and Melfort. *Napus* canola had a higher grain yield than *juncea* canola at Swift Current and flax had a higher grain yield than sunflower at Redvers.

The adjusted gross return of *napus canola* and sunflower (Figure 1.3) and flax and *juncea* canola (Figure 1.4) are presented. The adjusted gross return for sunflowers and *juncea canola* was similar from 10 to 70 kg N ha^{-1} when crop prices are low and N costs high (Figure 1.4) . At N rates greater than 70 kg N ha^{-1} the adjusted gross return declined. The adjusted gross return for sunflower indicated that there was no advantage to increasing N rate as the sunflower price increased and fertilizer cost decreased. A small increase in the adjusted gross return of *juncea* canola could be captured by increasing the N rate to 90 kg ha^{-1} as the crop price increased and fertilizer cost decreased. The adjusted gross return of flax did not increase above 50 kg N ha^{-1} when crop prices are low and N prices high (Figure 1.3). As the flax price increased, the adjusted gross return for flax was optimized at 90 kg ha^{-1}. The adjusted gross return of *napus* canola was very similar across a wide range of N rates when crop prices are low. As the price of *napus* canola increased the adjusted gross return was maximized at 110 kg ha^{-1}.

Plant density differed among the species with flax having the highest plant density and sunflower having the lowest (Tables 1.1 and 1.3). There was a linear decreased of 10% as the N rate increased. Days to first flower was affected by location, species and a location x species interaction, however, the flowering period in days was not affected by any of the treatments (Tables 1.1 and 1.4). Height was affected by location, species, N, location x species and species x N (Tables 1.1). No location tended to consistently have the tallest or shortest plants (Table 1.4). There was a curvilinear increase in the height of napus canola and juncea canola as the N rate increased (Table 1.5). The height of flax followed a similar but not significant trend $P = 0.07$. Kernel weight was affected by species, N, location x species and species x N (Table 1.1). As the N rate increased the kernel weight of Sunflower decreased while N rate had no effect on the kernel weight of the other species (Table 1.5). In addition the kernel weight of sunflower differed among the locations while the kernel weight of the other species was not affected by location (Table 1.4).

Test weight and protein were affected by the treatments used in this experiment while oil content was not. Test weight was affected by location, species, N, and location x species (Table 1.1).

There was a small linear increase in test weight as the N rate increased (Table 1.3). Test weight varied among the locations with Swift current having a lower flax test weight than Redvers but a higher juncea canola test weight than Indian Head and a higher sunflower test weight than Melfort and Redvers. The protein concentration was affected by species, N, location x species and location x nitrogen (Table 1.1). The protein concentration at Swift Current when averaged over all species increased in a curvilinear response as the N rate increased (Figure 1.5). At the other locations there was a linear increase in protein as the N rate increased. The rate of this linear response was lower at Redvers compared to Indian Head or Melfort. The protein concentration of flax differed among the locations with the flax grown at Swift Current having a higher level of protein than flax grown at Melfort (Table 1.6). The Protein level of the other species did not vary among the locations. Oil content was not affected by any of the factors (Table 1.1) and the means are presented in Table 1.3.

Conclusions

1) Current cultivars of *juncea* and sunflower are less responsive to applied N than current cultivars of *napus* canola and flax.
2) *Juncea* canola did not have an advantage over *napus* canola under the dry conditions that prevailed at Swift Current.
3) The gain yield of sunflower was only similar to *napus* canola and flax at Swift Current, the driest location with the longest growing season.
4) Shorter season sunflower hybrids are required to improve grain yield in Saskatchewan.
5) The adjusted gross return indicates that producers using a wide range of N rates may have a similar adjusted gross return.
6) A full economic analysis needs to be carried out on this data set before publication.

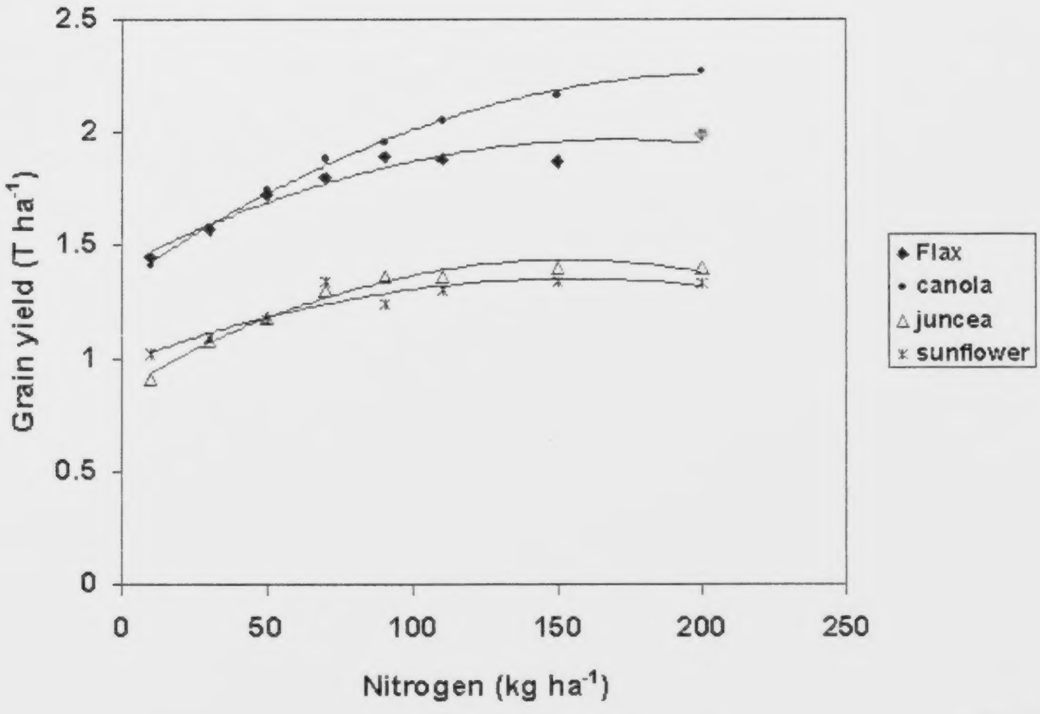

Figure 1.1 The effect of nitrogen rate on the grain yield of the oilseed crops average across locations and years. All species had a significant quadratic in grain yield to nitrogen rate.

Table 1.1 Analysis of variance for the effect of location, species and nitrogen on the growth and development of oilseed crops across Saskatchewan (2004-2006)

	Grain yield	Plant density	First flower	Flowering period	Height	Kerel weight	Test weight	Water use[Z]	Protein	oil
location (loc)	**0.0129**	0.0842	**<.0001**	0.4189	**0.0343**	0.113	**0.0289**	**0.007**	0.0814	0.7732
species	**0.0075**	**<.0001**	**0.0001**	0.0953	**<.0001**	**<.0001**	**<.0001**	0.0812	**0.0011**	0.8613
nitrogen	**<.0001**	0.1019	0.9797	0.7048	**<.0001**	**0.0056**	**0.0246**	0.6991	**<.0001**	0.6834
loc*species	**<.0001**	0.1816	**<.0001**	0.6922	**<.0001**	**0.035**	**<.0001**	**0.0004**	**0.001**	0.2867
loc*nitrogen	**0.0024**	0.2075	0.6879	0.598	0.2642	0.8106	0.3424	0.1088	**<.0001**	0.6077
species*nitrogen	**0.0261**	0.5795	0.9897	0.7285	**0.0032**	**<.0001**	0.3862	0.6181	0.0807	0.7912
loc*species*nitrogen	0.9996	0.5478	0.8979	0.7851	0.9937	0.9338	0.8057	0.8679	0.3859	0.87

[Z] water use to a depth of 3 feet

Table 1.2 The effect of location and species on grain yield

Location	Indian Head	Swift Current	Melfort	Redvers
	Grain Yield (kg ha^{-1})			
Flax	2.0557 *a*	1.416 *ab*	2.1357 *a*	1.477 *a*
Napus canola	2.1458 *a*	1.6409 *ab*	2.4208 *a*	1.3205 *ab*
Juncea canola	1.4395 *b*	1.1426 *b*	1.2713 *b*	1.1396 *ab*
Sunflower	1.1261 *b*	1.4908 *ab*	1.3051 *b*	0.9912 *b*

Bonferroni method was used for means seperation

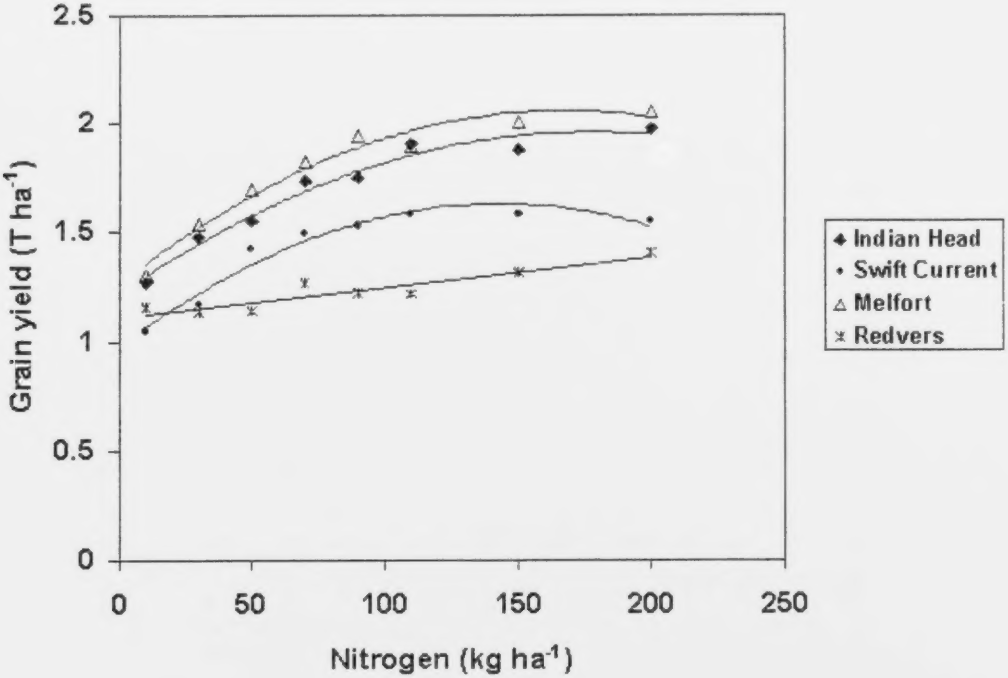

Figure1.2 The effect of nitrogen rate and location on grain yield average across species and years .

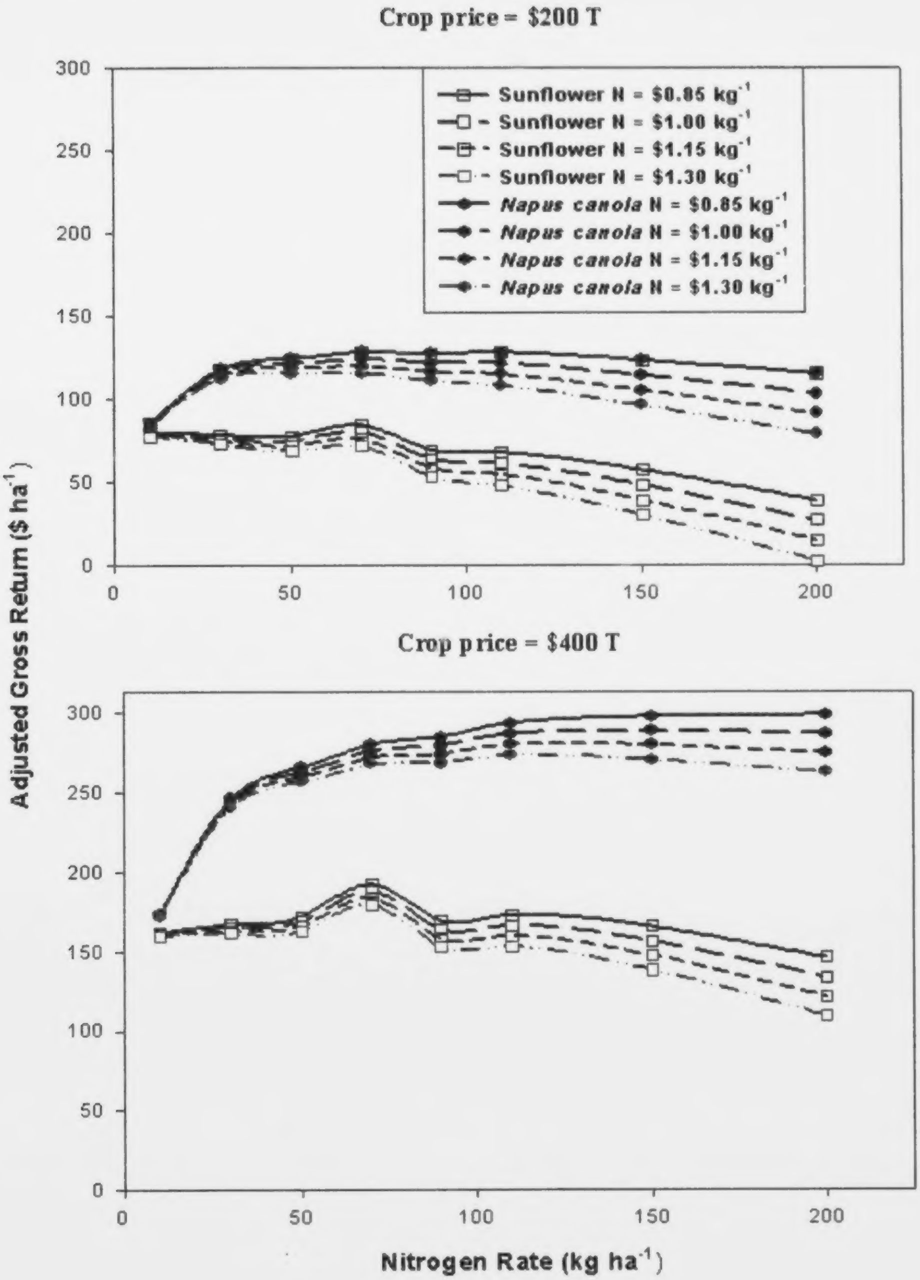

Figure 1.3 Adjusted gross return of napus canola and sunflower in response to changes in nitrogen rate averaged over years and locations.

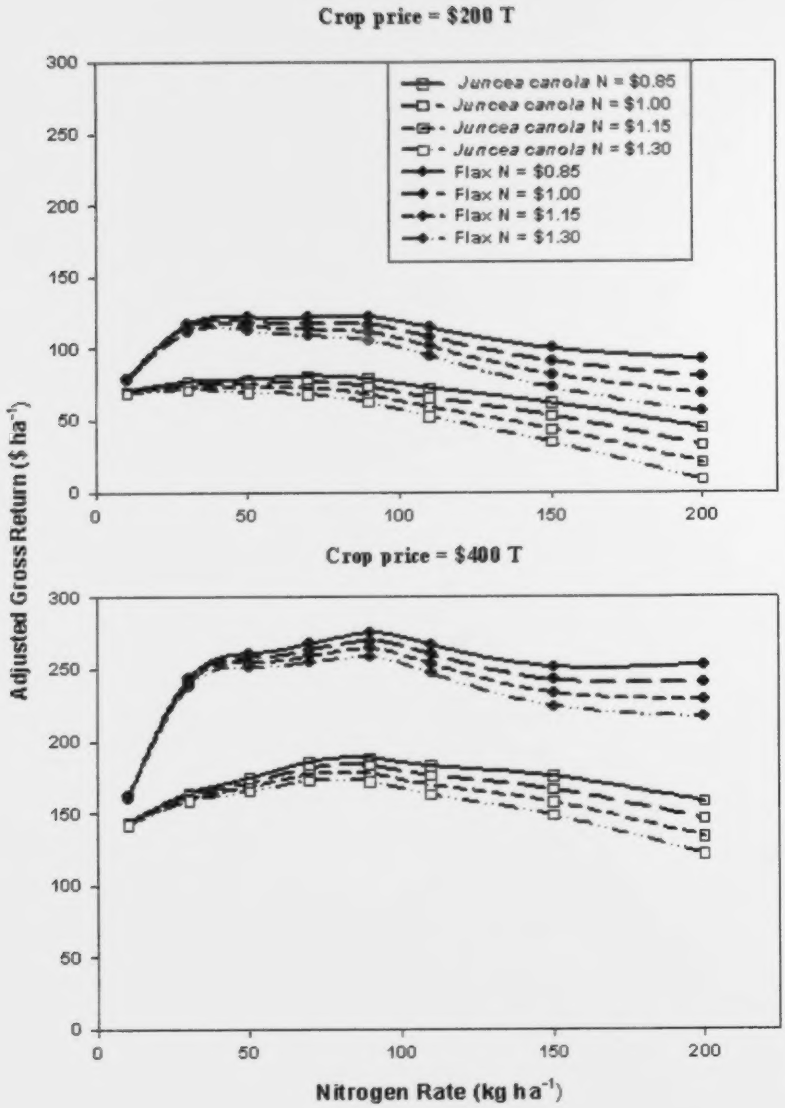

Figure 1.4 Adjusted gross return of juncea canola and flax in response to changes in nitrogen rate averaged over years and location

Table 1.3 The effect of location, species and nitrogen rate on several measured variables.

	Plant Density plant m^{-2}	First flower days	Flowering days	Water use (to 90 cm) mm	Test weight g 0.5L^{-1}	Oil %
Location						
Indian Head	204		26			47.6
Swift Current	165		24			53.3
Melfort	160		31			53.0
Redvers	248		17			46.5
Species						
Flax	504*a*		16			45.7
Napus canola	141*b*		21			50.3
Juncea canola	117*b*		33			52.7
Sunflower	15*c*		28			51.7
Nitrogen (kg ha^{-1})						
10	205	56	31	50	58.3	61.6
30	195	56	21	50	58.5	47.4
50	196	56	21	50	58.6	47.5
70	197	56	21	49	58.7	47.0
90	197	56	21	49	59.0	46.5
110	190	56	36	50	58.5	59.9
150	189	56	22	50	59.2	45.6
200	185	56	21	50	59.4	45.3
contrasts						
linear	**0.0022**	0.4394	0.7296	0.2753	**0.0004**	0.3748
Quad	0.8371	0.8027	0.9301	0.2451	0.6735	0.7761
Cubic	0.6692	0.6257	0.2944	0.52	0.6988	0.2761

Table 1.4 The effect of location and species on height, first flower and kernel weight

	Flax	Napus canola	Juncea canola	Sunflower
Location		*height (cm)*		
Indian Head	65*a*	92*b*	105*a*	134*a*
Swift Current	61*a*	105*a*	109*a*	112*b*
Melfort	60*a*	84*b*	90*b*	127*a*
Redvers	56*a*	88*b*	102*a*	129*a*
		first flower (days)		
Indian Head	61*a*	51*a*	50*a*	80*a*
Swift Current	58*ab*	50*a*	48*ab*	79*a*
Melfort	56*b*	45*b*	44*b*	78*a*
Redvers	58*ab*	39*c*	37*c*	68*a*
		kernel weight (g 1000 kernels^{-1})		
Indian Head	5.1*a*	3.1*a*	2.5*a*	39.1*bc*
Swift Current	5.0*a*	2.8*a*	2.4*a*	40.4*ab*
Melfort	5.9*a*	3.3*a*	2.4*a*	35.2*c*
Redvers	5.6*a*	3.3*a*	2.7*a*	43.6*a*

Bonferroni method was used for means seperation

Table 1.5 The effect of nitrogen and species on height and kernel weight

Nitrogen (kg ha^{-1})	Flax	Napus canola	Juncea canola	Sunflower
		height (cm)		
10	58	85	92	122
30	60	87	99	126
50	60	92	101	127
70	60	92	103	125
90	61	94	105	127
110	63	97	103	126
150	61	96	106	128
200	61	97	105	123
contrasts				
linear	0.0703	**<.0001**	**<.0001**	0.5527
Quad	0.2383	**0.0007**	**<.0001**	**0.0061**
Cubic	0.8975	0.658	0.0628	0.7824
Nitrogen (kg ha^{-1})		*kernel weight (g 1000 kernels^{-1})*		
10	5.6	3.1	2.5	38.1
30	5.5	3.2	2.5	38.5
50	5.3	3.1	2.5	38.7
70	5.4	3.1	2.5	39.4
90	5.4	3.1	2.5	39.8
110	5.4	3.1	2.5	39.5
150	5.4	3.1	2.5	41.4
200	5.4	3.1	2.5	41.0
contrasts				
linear	0.7556	0.9824	0.9413	**<.0001**
Quad	0.6743	0.9776	0.9502	0.2262
Cubic	0.6927	0.9993	0.9188	0.1917

Table 1.6 The effect of location and species on height, first flower and kernel weight

	Flax	Napus canola	Juncea canola	Sunflower
Location		*test* weight *(g 0.5L⁻¹)*		
Indian Head	70*ab*	64*a*	61*b*	38.3*ab*
Swift Current	67*b*	66*a*	66*a*	41.9*a*
Melfort	69*ab*	64*a*	64*ab*	33.5*c*
Redvers	72*a*	63*a*	65*ab*	35.4*bc*
		protein (%)		
Indian Head	21.8*ab*	20.9*a*	25.3*a*	17.4*a*
Swift Current	24.7*a*	23.1*a*	25.6*a*	19.2*a*
Melfort	21.7*b*	20.7*a*	25.0*a*	15.4*a*
Redvers	23.2*ab*	23.8*a*	25.3*a*	16.9*a*

Bonferroni method was used for means seperation

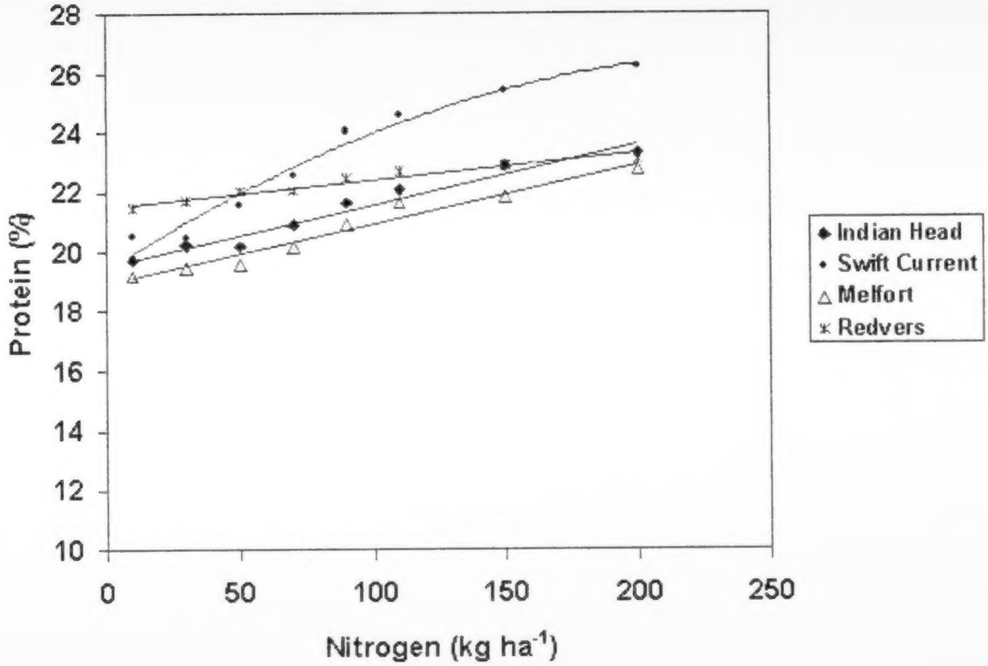

Figure 1.5 The effect of nitrogen and location on protein of 4 oilseed crops.

B. Experiment 2

The re-cropping of malting Barley on four oilseed crops and several nitrogen fertilizer rates

The analysis of variance for all the measured variables is presented in Table 2.1. Soil residual Nitrogen (N) was affected by the N rate used on the previous crop (Pcrop), and two interactions location x Pcrop and location x N (Table 2.1). When measured in the fall before seeding, there was a curvilinear increase in soil residual nitrogen at Indian Head Swift Current and Melfort and a linear increase at Redvers (Table 2.2). The soil had lower levels of residual N when the previous crop was sunflowers than flax and napus canola at Indian Head and than flax and juncea canola at Swift Current (Table 2.3). Pcrop had no effect on soil residual N at Melfort and Redvers.

Plant density was affected by location and the Pcrop x N interaction (Table 2.1). The plant density of barley was higher at Indian Head than at the other locations (Table 2.4). Although there was a significant Pcrop x N interaction it does not appear to be of any biological significance with any clear trend (Table 2.4).

The head density of barley was affect by Pcrop, N and the interaction of Pcrop x N (Table 2.1). There was a linear increase in head density on all four Pcrops as the N rate increased (Table 2.5). The increase in head density which is a yield component indicates that the barley was taking up the extra soil residual N and using the N to facilitate growth and development. Kernel weight was affected by location, Pcrop, N, Location x Pcrop and location x N (Table 2.1) At Swift Current there was a linear decrease in kernel weight as the N rate applied to the previous crop increased (Table 2.6). This trend did not occur at the other locations. In addition the kernel weight of barley was lower at Swift Current than at Indian Head and Melfort after all four crops (Table 2.7).

Barley height was affected by location, N and Pcrop x N (Table 2.1). Barley was taller at 54% taller at Swift Current compared to Melfort (Table 2.4). Barley height increased linearly on all previous crops as the N rate on the previous crop increased (Table 2.8). In addition there was a cubic but not quadratic response on the flax stubble as the N rate increased. This increase in height is another indication that the barley crop is detecting and using the extra residual N left by the higher N rates used on the previous oilseed crops.

Location, Pcrop, N, location x N, and Pcrop x N all had an effect on the grain yield of barley. There was a linear increase in grain yield as the N rate applied to the previous crop increased (Fig. 2.1). Indian Head and Melfort started had a higher yield at low N rates than Swift Current and Redvers. Indian Head appeared to be the most responsive location to N rate while Redvers appeared to be the least responsive site to N rate. There was a linear increase in grain yield as the N rate increased on all previous crops (Fig. 2.2). In addition, there was a significant cubic response to N rate when the Pcrop was flax. These results indicate that the N rate applied to the previous crop will have an effect on grain yield across a wide range of locations and Pcrops when a low rate of N 40 kg ha^{-1} is used on the barley crop grown after an oilseed crop.

Protein concentration in the grain was affected by N, location x Pcrop and location x N (Table 2.1). There was a significant linear increase in the grain protein of barley as the N rate applied to the previous crop increased (Fig. 2.3). In addition, there was a significant curvilinear increase in protein at Swift Current as the N rate increased. When the location x Pcrop was examined we found that *napus* canola had a lower level of protein than the other Pcrops at Swift Current (Table 2.3). There

were no differences among the Pcrops at the other locations. In general the protein levels were below the maximum level allowed for malting barley. Further research will be required to determine if the effect of the N rate on the Pcrop would disappear if higher rates of N were applied to the barley in the year it is grown. Total grain N was affected by nitrogen and location x Pcrop (Table 2.1). There was a curvilinear increase in total grain N from 50.2 to 66.9 kg ha^{-1} as the N rate increased (Table 2.8). This would be expected since both protein and grain yield of the barley increased as the N rate increased. Redvers had less total grain N than Indian Head when the Pcrop was flax or *napus* canola less total grain N than Melfort when the Pcrop was sunflower. This is a result of both the low yield and protein levels observed at Redvers.

Test weight, plump seed and thin seed had a very similar response to N and location. The location x N interaction was significant for all three variables (Table 2.1). There was a curvilinear decrease in test weight and a linear decrease in plump seed of barley at Swift Current as the N rate applied to the previous crop increased (Tables 2.6 and 2.9). Thin seed underwent a linear as the N rate increased. N rate had no effect on test weight, plump seed or thin seed at any other location. This indicates that at a site like Swift Current where water is often yield limiting the application of excess N can have detrimental effects on the quality of crops even when the nitrogen is applied in the previous year.

Table 2.1 Analysis of variance for the effect of location, stuble and residual nitrogen on the growth and development of barley across Saskatchewan (2005-2007)

	Soil Residual N	Plant density	Head Density	Height	Kernel weight	Grain yield	Protein	Total grain N	Test weight	Plump seed	Thin Seed
location (loc)	0.5591	**<.0001**	0.2534	**0.0088**	**0.0001**	**0.0129**	0.2529	0.0517	0.3912	**0.0021**	**0.0075**
previous crop (Pcrop)	0.0663	0.5083	**0.0011**	0.1044	**0.0434**	**0.0274**	0.1751	0.4024	0.0159	0.2172	0.5426
nitrogen	**<.0001**	0.7456	**<.0001**	**<.0001**	**0.0162**	**<.0001**	**<.0001**	**<.0001**	**0.0161**	**<.0001**	**<.0001**
loc*Pcrop	**0.0220**	0.3359	0.1778	0.1929	**0.0002**	0.0659	**0.0158**	**0.0124**	0.6106	0.0622	0.1363
loc*nitrogen	**0.0086**	0.7466	0.3596	0.3687	**<.0001**	**0.0019**	**<.0001**	0.5911	**<.0001**	**<.0001**	**<.0001**
Pcrop*nitrogen	0.1164	**0.0229**	**0.0337**	**0.0026**	0.9985	**0.0142**	0.3606	0.0571	0.9332	0.9861	0.9986
loc*Pcrop*nitrogen	0.9458	0.7677	0.9126	0.6354	0.9998	0.9762	0.9998	0.9989	1.0000	1.0000	1.0000

Table 2.2 The effect of nitrogen and location on soil residual nitrogen

Nitrogen (kg ha^{-1})	location: Indian Head	Swift Current	Melfort	Redvers
	soil residual nitrogen (kg ha^{-1})			
10	18.9	12.3	13.4	12.2
30	20.3	11.1	15.8	13.7
50	19.6	14.6	15.8	15.0
70	18.5	14.0	18.8	13.9
90	21.4	17.5	21.1	20.1
110	25.5	19.5	21.5	19.5
150	30.3	26.4	31.0	18.1
200	40.8	46.6	41.2	24.2
contrasts				
linear	**<.0001**	**<.0001**	**<.0001**	**0.000**
Quad	**0.008**	**<.0001**	**0.039**	0.889
Cubic	0.794	0.313	0.910	0.628

Table 2.3 The effect of location and species on spring soil residual nitrogen and the grain protein of barley

	Indian Head	Swift Current	Melfort	Redvers
previous crop		*spring soil residual nitrogen (kg ha^{-1})*		
Flax	28.1 a	25.8 a	22.7 a	18.1 a
Napus canola	30.9 a	14.9 b	24.9 a	18.5 a
Juncea canola	23.3 ab	25.3 a	24.6 a	17.4 a
Sunflower	15.4 b	15.1 b	17.2 a	14.2 a
		grain protein (%)		
Flax	9.6 a	11.2 a	9.5 a	8.6 a
Napus canola	9.4 a	10.2 b	9.3 a	8.7 a
Juncea canola	9.3 a	11.1 a	9.1 a	8.5 a
Sunflower	9.0 a	11.2 a	9.5 a	8.4 a

Bonferroni method was used for means seperation

Table 2.4 The effect of location on plant density, head density and height and the effect of previous crop on test weight plump seed and thin seed

Location	Plant Density plants m^{-2}	Head density heads m^{-2}	Height (cm)
Indian Head	245.34 *a*	459.61 *a*	77.8507 *ab*
Swift Current	143.56 *b*	380.31 *a*	89.5486 *a*
Melfort	160.72 *b*	441.19 *a*	58.3231 *b*
Redvers	183.91 *b*	425.04 *a*	71.3567 *ab*
	Test weight	plump	thin
Previous Crop	g 0.5L^{-1}	%	%
Flax	307.54 *a*	55.6237 *a*	2.3179 *a*
Napus canola	307.66 *a*	56.4074 *a*	1.8582 *a*
Juncea canola	305.57 *ab*	55.5903 *a*	2.0837 *a*
Sunflower	305.2 *b*	55.3678 *a*	2.2411 *a*

Table 2.5 The effect of nitrogen and stubble on plant density and head density

Nitrogen (kg ha^{-1})	Stubble			
	Flax	Napus canola	Juncea canola	Sunflower
		plant density (plants m^{-2})		
10	178	188	180	195
30	190	181	183	178
50	176	178	183	184
70	183	172	189	186
90	188	180	185	186
110	183	173	196	190
150	184	180	181	189
200	185	175	191	178
contrasts				
linear	0.451	0.116	0.113	0.303
Quad	0.661	0.121	0.326	0.557
Cubic	0.782	0.135	0.262	**0.008**
Nitrogen (kg ha^{-1})		Head density *(heads m^{-2})*		
10	401	396	408	388
30	392	437	417	396
50	398	414	425	383
70	408	426	448	394
90	464	421	423	404
110	471	444	436	406
150	463	467	454	424
200	484	466	446	445
contrasts				
linear	**<.0001**	**<.0001**	**0.005**	**<.0001**
Quad	0.182	0.841	0.280	0.280
Cubic	0.104	0.626	0.962	0.687

Table 2.6 The effect of nitrogen and location on kernel weight and test weight

Nitrogen (kg ha^{-1})	Indian Head	Swift Current	Melfort	Redvers
			kernel weight (g 1000 kerenls^{-1})	
10	41.2	34.1	44.2	38.7
30	41.5	33.5	44.1	38.2
50	40.9	33.3	44.3	37.9
70	41.8	32.9	44.1	37.9
90	41.2	32.3	44.4	38.7
110	41.7	31.8	44.2	38.9
150	41.1	31.4	44.6	38.3
200	41.7	30.5	44.6	38.7
contrasts				
linear	0.373	**<.0001**	0.095	0.375
Quad	0.910	0.349	0.768	0.690
Cubic	0.413	0.938	0.633	0.244
Nitrogen (kg ha^{-1})		test weight *(g 0.5L^{-1})*		
10	303	307	315	308
30	304	304	314	308
50	303	302	315	308
70	303	297	317	309
90	305	297	315	310
110	304	295	315	309
150	305	293	314	310
200	305	289	316	310
contrasts				
linear	0.250	**<.0001**	0.817	0.225
Quad	0.973	**0.013**	0.988	0.716
Cubic	0.909	0.363	0.271	0.705

Note: the four location columns are grouped under the spanning header "location".

Table 2.7 The effect of location and previous crop on total grain nitrogen and kernel weight of barley

	Flax	Napus canola	Juncea canola	Sunflower
Location		*total grain nitrogen (kg ha^{-1})*		
Indian Head	70.8 *a*	69.5 *a*	66.7 *a*	53.7 *ab*
Swift Current	59.4 *ab*	54.4 *ab*	55.2 *a*	47.3 *ab*
Melfort	60.0 *ab*	63.3 *ab*	61.6 *a*	64.4 *a*
Redvers	43.4 *b*	40.3 *b*	41.4 *a*	35.7 *b*
		kernel weight (g 1000 kernels^{-1})		
Indian Head	41.6 *a*	41.6 *a*	40.8 *a*	41.5 *a*
Swift Current	32.7 *b*	33.5 *b*	32.2 *b*	31.6 *b*
Melfort	44.1 *a*	43.9 *a*	44.0 *a*	45.2 *a*
Redvers	38.6 *ab*	38.7 *ab*	38.2 *ab*	38.1 *ab*

Bonferroni method was used for means seperation

Table 2.8 The effect of nitrogen and stubble on height and total nitrogen harvested in grain

Nitrogen (kg ha^{-1})	Stubble			
	Flax	Napus canola	Juncea canola	Sunflower
		height (cm)		
10	74	73	75	70
30	-	73	75	69
50	74	74	76	69
70	75	73	74	69
90	76	74	75	71
110	78	75	75	72
150	81	75	76	73
200	82	77	77	75
contrasts				
linear	**<.0001**	**<.0001**	**0.043**	**<.0001**
Quad	0.593	0.194	0.056	0.088
Cubic	**0.012**	0.903	0.815	0.105

Nitrogen (kg ha^{-1})	all stubles *total grain N (kg N ha^{-1})*
10	50.2
30	50.7
50	50.6
70	52.3
90	54.8
110	56.2
150	62.0
200	66.9
contrasts	
linear	**<.0001**
Quad	**0.008**
Cubic	0.124

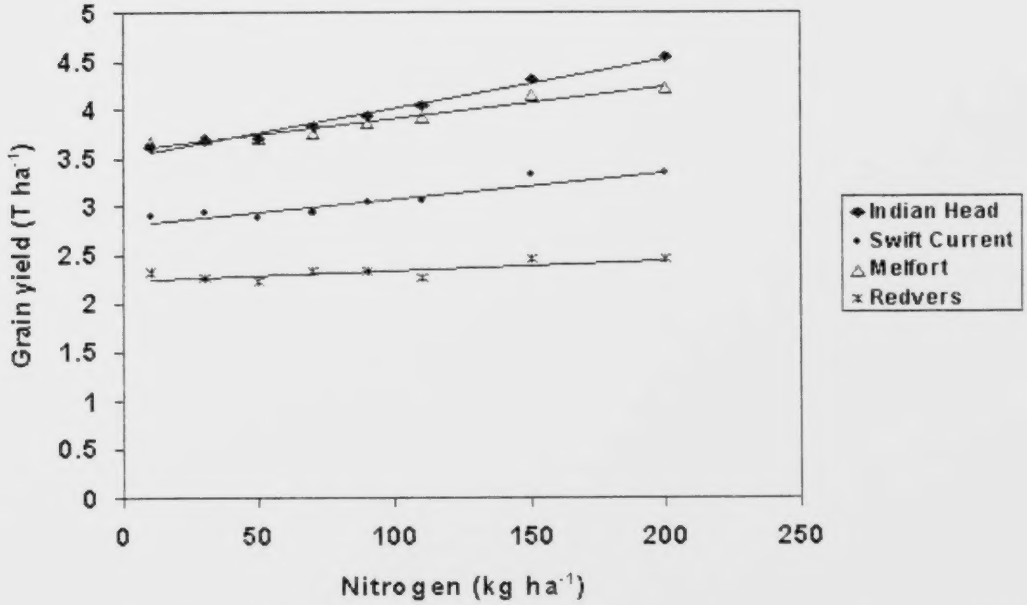

Figure 2.1 The effect of location and nitrogen applied to the previous crop on the grain yield of barley

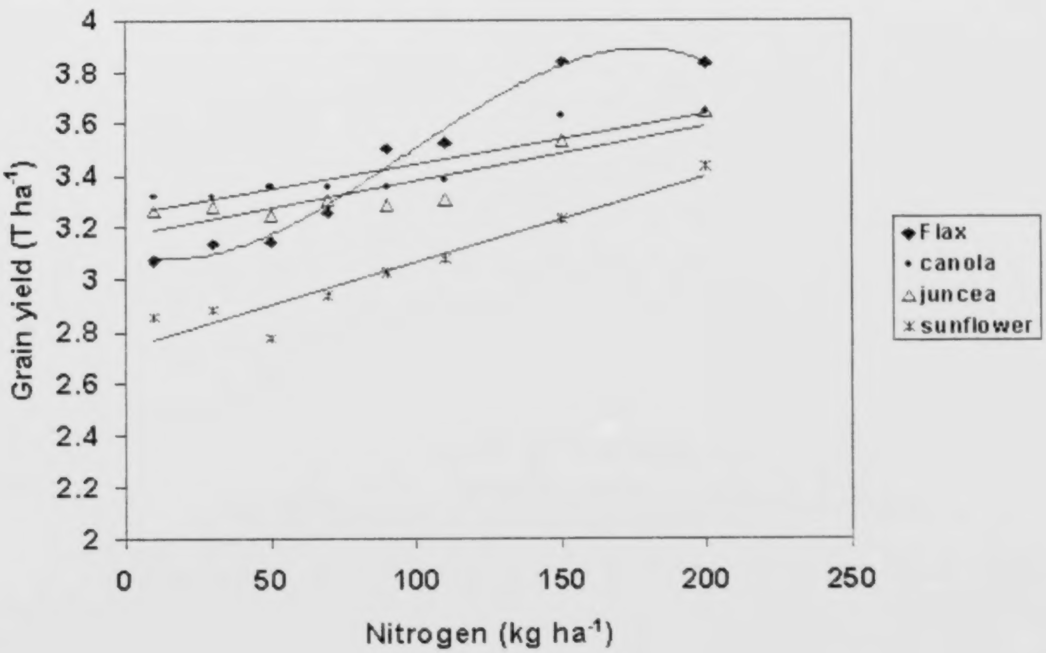

Figure 2.2 The effect of previous crop and nitrogen applied to the previous crop on grain yield

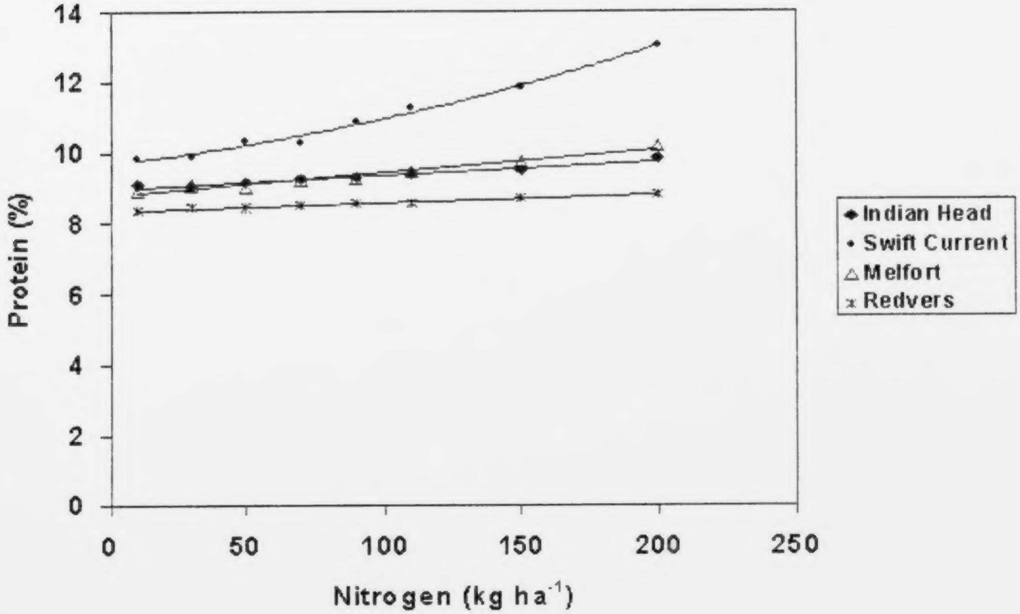

Figure 2.3 The effect of location and nitrogen applied in the previous year on the grain protein of barley

Table 2.9 The effect of nitrogen and location on kernel weight and test weight				
	location			
Nitrogen (kg ha^{-1})	Indian Head	Swift Current	Melfort	Redvers
		plump seed (%)		
10	59.9	41.6	64.2	63.8
30	60.3	40.9	63.9	63.3
50	59.3	37.9	64.0	62.8
70	59.8	36.6	64.0	63.2
90	59.8	36.6	63.8	63.7
110	59.9	32.8	63.9	63.4
150	59.2	32.0	64.0	63.6
200	59.7	28.8	64.0	63.3
contrasts				
linear	0.620	**<.0001**	0.908	0.995
Quad	0.797	0.109	0.801	0.899
Cubic	0.847	0.961	0.892	0.505
Nitrogen (kg ha^{-1})		*Thin seed (%)*		
10	1.1	4.0	0.5	0.5
30	1.0	3.9	0.6	0.6
50	1.2	5.6	0.5	0.9
70	1.2	5.4	0.6	0.7
90	1.1	5.9	0.7	0.7
110	1.1	7.0	0.6	0.8
150	1.3	7.6	0.6	0.8
200	1.2	8.9	0.7	0.6
contrasts				
linear	0.752	**<.0001**	0.686	0.897
Quad	0.913	0.580	0.950	0.686
Cubic	0.998	0.861	0.897	0.949

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Nuttall, W.F. and S.S. Malhi, 1991. The effect of time and rate of N application on the yield and N

uptake of wheat, barley, flax, and four cultivars of rapeseed. Can. J. Soil Sci. 71:227-238.

VI Extension activities

a. Research presented at Indian Head Agricultural Research foundation's Zero-till Field day on July 19th

b. Adaptation of oilseed crops in Saskatchewan. IHARF Winter Seminar & Annual Meeting, Indian Head, Jan 19, 2005

c. Tour for Westco Aces, Scott Research Farm, July 2005.

d. Field Tour on the Use of Everest on Flax and Oilseed Adaptation in Western Canada for Agricore United Agronomists. July 5th, 2005.

e. Economic adaptation of oilseed crops across Saskatchewan. Pages 25-30 in Proceedings of the Zero Till Crop Management Field Day 2005. Indian Head, SK. July 19, 2005

f. Adaptation of oilseed crops in Saskatchewan, Sunflower "The Big Picture Crop". January 24, 2006, Heritage Inn, Moose Jaw, SK.

g. Managing perennial weeds, Oilseed adaptation and Canaryseed agronomy, IHARF Winter Seminar, January 26, 2006, Indian Head Memorial Hall, Indian Head, SK.

h. May, W.E., Gan, Y., Brandt, S.A., Kutcher, R. and Lafond, G.P. 2006. Adaptation of oilseeds in Saskatchewan.Pages 103-107 in Proceedings of the Annual Meetings of the Saskatchewan Soil Conservation Association. February 15th -16th, Regina, SK. 145 pages.

i. Adaptation of oilseed crops in Saskatchewan, SPARC, Field Day Tour, July 13th, Swift Current, SK.

j. Tour of the Indian Head Research Farm and on-going research for producers from West Australia. The main theme of the Australian tour was the production of GMO canola. There were 23 people present on the tour.

k. May, W.E., Gan, Y., Brandt, S.A., Kutcher, R. and Lafond, G.P. 2006. Adaptation of oilseed crops in Saskatchewan. Pages 69-73 in Proceedings of the 2006 Indian Head Crop Management Field Day. July 18th, 2006. 83 pages.

l. Oilseed advantages on the prairies, Top Crop Manager, March 2007, pp 102-104.

m. Sunflower Agronomy, Sunflower Futures- A Look Ahead, Sunflower industry information session and research plot tour, Wednesday, June 27, 2007, Saskatoon, SK.

n. May, W.E., Gan, Y., Brandt, S.A., Kutcher, R. and Lafond, G. 2007. The response of sunflower, Brassica juncea canola, Brassica napus canola and flax to nitrogen in Saskatchewan. Page 51-3. The ASA-CSSA-SSSA International Annual Meetings, Nov 4-8, 2007. New Orleans, Louisiana, US.

o. Plan to make presentation at 2008 Soil and Crop Workshop

p. Pictures are available upon request